Normally, the receiver only uses the 100-baud-section to achieve a fast synchronization. The 200-baud-section supplies additional information about the channel quality: if it is received correctly, the first CS will be CS4, otherwise CS1 is sent. After in turn having synchronized a CS4 or CS1, the master will continue with sending normal data packets at 200 or 100 baud, respectively. The first transmitted characters contain the 'system level number' (PACTOR software-version), followed by the master address (callsign).

5. Changing the transmission direction

Similar to AMTOR, the receiving station (RX) can change the transmission direction whenever it has received a valid packet. For this purpose a special changeover-packet is transmitted, starting at the CS time frame. The transmitting station (TX) will switch to RX mode immediately after it has received the CS3 which forms the first section of the changeover-packet. It then reads in the rest of that packet and transmits a CS (CS1 and CS3 = acknowledge, CS2 = reject) timed at the last three bytes of the former packet frame. To force a break in, the TX sets the BK-status-bit (this corresponds to AMTOR '+ ?').

6. Speedchange

Speeddown only being useful in poor conditions or at low data input rates (e. g. manual typing), both directions are treated unsymmetrically.

i) Speeddown

The RX may request speeddown after any incorrectly received packet by sending CS4, which immediately forces the TX to build up 100-baud-packets (any unconfirmed 200 baud information is repeated at low speed).

ii) Speedup

Any valid packet may be confirmed with CS4, forcing a TX speedup. In case the following high-speed-packet is not acknowledged after a number of

8. Data Compression

Character frequency analysis of typical english or german texts shows that the average amount of information per character does not exceed 4 bits. For that reason, ASCII text transmissions often carry a redundancy of 50%, which could be avoided by using a vriable length code matched to the character distribution. The most popular example of such a code is the Morse code; PACTOR data compression mode applies Huffman coding with nearly optimum efficiency, yielding up to 100% speed gain. Every packet contains a compressed data string; character code lengths vary from 2 to 15 bits.

9. Memory ARQ

In conventional ARQ systems the TX has to repeat a packet until it has been received completely error-free. It is evident that the probability of receiving a complete packet dramatically decreases with lower S/N ratio. The only way to maintain the contact in that case is to shorten packet length and/or to apply error correcting codes which in turn will greatly reduce maximum traffic speed when conditions are good.
The method chosen by WAA Research Group is to sum up corresponding bit samples of subsequent packets and to test if the mean value (reduced to a 0/1-decision) passes the CRC. To keep quantizing errors small, the samples are taken from the FSK-demodulator low-pass-filter output by means of an 8-bit AD-converter. Assuming white Gaussian noise, this accumulation method - also known as 'memory ARQ' - will obviously converge even at a low S/N ratio. Furthermore, since shift levels are toggled with every transmission, constant interfering signals within the receiver passband will not affect the resulting mean value. To prevent accumulation of old request packets, the header is inverted with every new information packet, thus serving as a RQ indicator (similarity test).

10. Listen Mode (Monitor)

This mode resembles Packet Radio monitoring: the receiver scans for valid packets which are detected by CRC match. This 'brute force' method was chosen in order to ensue maximum flexibility, although it consumes a considerable amount of the available CPU capacity.

11. FEC Transmissions

CQ and bulletin transmissions are supported by means of a special non-protocol mode. Packets are transmitted with one or more repetitions; the CS receive gap is omitted. Since the listen mode does not require synchronization, the transmitting station possesses great freedom of selecting packet repetition rateand speed.

12. Practical Aspects

The first PACTOR programs were running on 'breadboarded' Z80 singleboard-computers. These early experiments led to the development of a stand-alone

'PACTOR- Controller' with built-in modem and tuning-display. The conven-

"Exhibit B"

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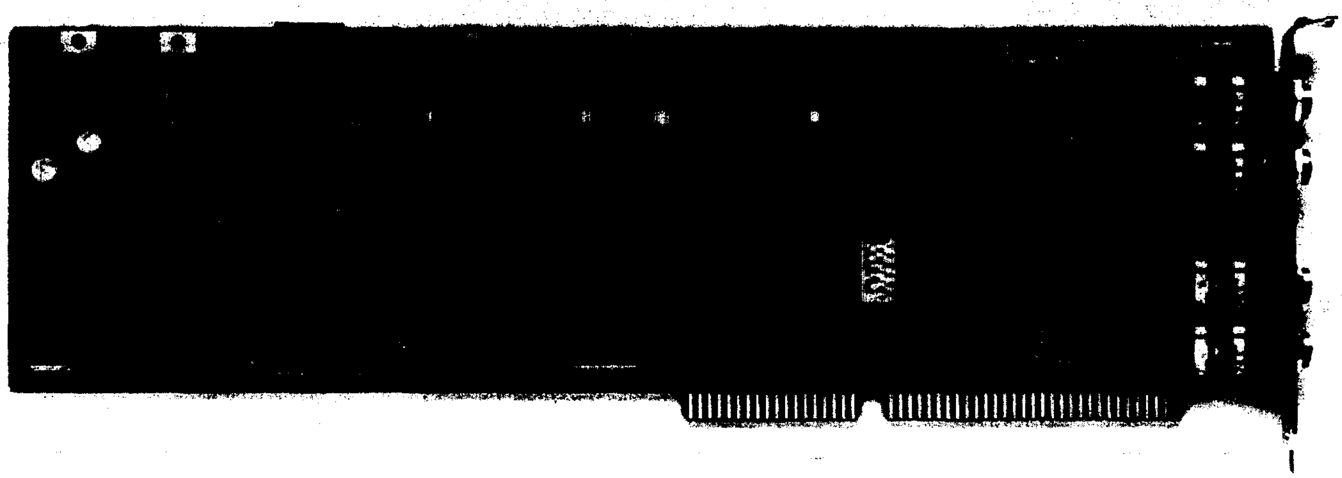
PCI-4000 / PC-CLOVER



CLOVER MODEM FOR HF DATA COMMUNICATION

PC-CLOVER is a hardware and software implementation of CLOVER modulation (patent pending). The modem provides bandwidth-efficient and high data rate transmission of error-corrected data in a format that is specifically tailored to meet the challenges of HF radio propagation. In ARQ modes, CLOVER modulation format is adaptively adjusted to maximize data

PCI-4000/ PC-CLOVER

SPECIFICATIONS

SIGNAL FORMAT:

Each 32 mSec data frame consists of 4 Dolph-Chebychev pulses interleaved in time and frequency. Each pulse is 32 mSec long and is displaced in time from the preceeding pulse by 8 mSec. The first pulse in a frame is centered at an odd multiple of 62.5 Hz and the remaining 3 pulses are centered at the next three higher odd multiples of 62.5 Hz, respectively. Each pulse occupies a bandwidth of 125 Hz, measured at the -60 dB points. The composite -50 dB bandwidth of a CLOVER emission is 500 Hz. The crest factor of CLOVER modulation is 2.0.

MODULATION FORMATS:

All modulation formats convey data in the differences between phase and/or amplitude of successive pulses at each of the 4 pulse frequencies.

BDIV: 4-Pulse diversity, Binary phase, 31.25 bits/sec
BPSK: 4-Pulse Binary Phase, 125 bits/sec
QPSK: 4-Pulse Quad Phase, 250 bits/sec
8PSK: 4-Pulse Eight Phase, 375 bits/sec
16PSK: 4-Pulse Sixteen Phase, 500 bits/sec
8P2A: 4-Pulse Eight Phase, Two Amplitude, 500 bits/sec:
Similar to 8PSK except that 8-dB amplitude shifts also occur, providing one more bit of data per pulse.
16P4A: 4-Pulse Sixteen Phase, 4 Amplitude, 750 bits/sec:
Similar to 16PSK except that amplitude shifts to one of four values (4 dB per step) provide 2 extra bits per pulse.

ECC FORMATS:

Reed-Solomon codes on GF(2e8) are generated and decoded with fast transform methods. The Massey-Berlekamp Algorithm synthesizes the feedback shift register which corrects the errors. Block sizes of 17, 51, 85, and 255 bytes with code rates of 60%, 75%, 90%, and 100% are used.

DATA FORMAT:

CLOVER modulation is bit transparent. Data supplied via the PC bus is demodulated at the receiving station in exactly the same bit order. Data compression and/or encryption may be used in PC-based application software.

DATA TRANSMISSION MODES:

FEC mode is used to send data from one station to one or more CLOVER-equipped stations. Modulation, block size, and coder rate are set manually by the transmitting station. Adaptive mode control is not available in FEC mode.

ARQ mode connects one CLOVER station to a second station. Data flow may be in either direction without the use of an " OVER" command. This is the radio analog of " full duplex" and maximizes data flow on the radio channel when large amounts of data must flow in both directions simultaneously. Automatic adaptive control of CLOVER modulation is provided in ARQ mode.

MONITOR mode allows any unconnected station with a CLOVER modem to listen to FEC and ARQ radio transmissions. Error correction is limited to the capacity of the Reed-Solomon encoder and code rate chosen by the sending station(s). Adaptive mode changes by the sending station will be followed as closely as possible by the monitoring modem, but adaptive feedback to the sending station(s) is not available in this mode.

MODEM SIGNAL PROCESSING:

DSP56001 DSP 24-bit processor, 8Kx24 bit RAM; software downloaded from host processor.

HOST AND PROTOCOL PROCESSOR:

68EC000 16-bit processor, 32Kx16 bit RAM, 16Kx16 bit ROM; software downloaded from PC bus.

PC INTERFACE:

16-bit interface to " PC-AT" bus; FIFO data buffers for all transmit and receive data. PC interface may be set via option jumpers to use I/O Address mapped, poll-select access or to use PC I/O Interrupt access. CLOVER operating software is downloaded via the PC-bus.

RADIO INTERFACE:

16-bit Sigma-Delta A/D converter for received data; dynamic range exceeds 90 dB. Audio input is 10K ohms, -60 to +10 dBm (.7 mV to 2.8 V rms). 16-bit D/A converter generates transmit modulation; spurious signals are at least 60 dB below peak output. Audio output is 600 ohms, adjustable from -40 to 0 dBm (7 mV to .7 V rms). Push-To-Talk (PTT) relay output (±50V, 100 ma). NPN open-collector SEL-CAL output (+50V, 100 ma). Tuning Indicator output (± 1 ma). All rear panel connectors are 1/4" " stereo" jacks (AF IN, AF OUT, PTT & SEL-CAL, TUNING).

RADIO REQUIREMENTS:

Radio equipment must be tunable in 10 Hz steps and be sufficiently stable to remain within ±25 Hz of the operating frequency while in communications.

FURNISHED ACCESSORIES:

Three 1/4" " stereo" plugs and tuning meter with cable and plug; Operator's Manual, HAL PC-CLOVER software diskette.

SOFTWARE:

HAL PC-CLOVER SOFTWARE: PC compatible software on one 5.25" diskette. Software features include split-screen, menu-driven commands, save-to-disk, send disk files, edit in transmit buffer, set CLOVER configuration, MYCALL entry and storage, HERE IS programmable messages.

THIRD-PARTY SOFTWARE: All network software authors are encouraged to write drivers for PC-CLOVER. A complete command protocol definition document is available free of charge to interested authors. Information regarding available " third-party" software will be provided to all CLOVER customers.

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A written copy of the applicable warranty may be obtained free of charge upon request. Specifications subject to change without notice.